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Innovation Benchmarking in the Telecom Industry

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Benchmarking: A surveyor's mark (...) of previously determined position (...) and used as a reference point (...) standard by which something can be measured or judged.

- Webster's Dictionary

1. Innovation Benchmarking

The pioneering work of Kearns at Xerox Corporation on benchmarking in management used the following working definition:

> "Benchmarking is the continuous process of measuring products, services and practices against the toughest competitors or those companies recognized as industry leaders." [1]

Later, a broader understanding in terms of action-oriented concepts led to the rather different approach of Camp: "Benchmarking is the search for industry best practices that lead to superior performance."[2]

Although benchmarking is relatively new, it is quite well established. The main problem with benchmarking is that most people use rather crude scores to carry out benchmarking comparisons. The purpose of this paper is to return to the original meaning and to propose a different type of benchmarking using quantitative measures, in order to position a product or service in terms of its technology.

This paper concentrates on the benchmarking of innovations, not of standard products or practices. This is not a critical remark toward standard benchmarking -- just another approach to achieving the same goal. In general, whenever one can use quantitative data organized, for example, as a table of data, one is better off than when qualitative judgments -- the conventional approach in benchmarking -- are made.

The structure of this paper is as follows: The first section explains how technological benchmarking can be carried out for strategic positioning of firms in global telecom markets (telecom manufacturers). Second, overall positioning of firms in the information technology market is discussed. Third, the way in which knowledge production leads to innovation and growth is explored. Fourth, specific positioning of firms in single-product quality within the area of telecom products is examined. Finally, the last section provides a typology of firms based on how well product quality, measured by the "technometric" approach, correlates with market-based preferences.

The methodological tools used for this quantitative benchmarking begin with patent statistics. But benchmarking is often not unidimensional, but rather multidimensional. So we need to use new tools to express fully the multidimensional nature of quality (strategic markets, strategic sub-technologies), such as multidimensional scaling (section 2).

Patent statistics are also useful for exploring the knowledge production that leads to innovation and subsequent growth (section 3). A technique known as technometric benchmarking is applied

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[1] D.T. Kearns, Quality Improvement Begins at the Top, in Bowles, ed., *World* 20 (5), pp. 21, 1986. The concept dates back to around 1979.

[2] R.C. Camp, *Benchmarking: the search for industry best practices that lead to superior performance*. Milwaukee: ASQC Quality Press, 1989, p. 12.

to give quantitative expression to the multidimensional nature of most products and services, i.e. to product quality (section 4).

For most people, a patent is a legal document. But what interests us in patent statistics is the quality of the output of knowledge that finds expression in patents. If in a company two engineers work for a year on a defined project funded from internal sources (cash flow), and if they are successful and invent something new, then we eventually have a document emerging from this lab that tells us that two engineers worked for a while on a certain invention, described very precisely. We can read from the document, as we read from scientific publications, that this company has deliberately brought about a certain inventive step, now documented and codified. So patent documents point to those areas of activity in which a company has invested R&D labor and resources. When patent examiners (in most countries civil servants at patent offices) discover that the idea is not new - but is already known - it matters to patent attorneys but little to us, because the fact remains, the company invested, say, two man-years in the R&D.

The fact that our world is still divided into national territories, and that intellectual property rights are protected by national patent offices and in national borders, mean that a patent protects an idea in one country and one market. Regional coverage of patent protection must be deliberately decided by a company. So when one invention, one patent application, is filed at home, it is a sign that a company intends to market it in the domestic market only. When patents are filed in seven or eight countries, it shows the company intends to either manufacture or market the product in many countries.

Patent analysis is difficult. We must treat the data with care. Some years ago, the OECD secretariat in Paris published a manual, a guideline, on what one should observe in working with patent documents.[3] All the possible mistakes one can make in analyzing patents are listed, so that one can prevent them if one reads this document carefully.

2. Positioning of firms in global telecom markets - an example of innovation benchmarking

Let us begin our study of innovation benchmarking with companies in the area of telecom manufacturing. The companies in our analysis are listed in Table 1. Our objective is to examine the marketing information inherent in patent statistics.

Let us examine Siemens first. Figure 1 shows the number of patent documents originating with Siemens (they have a number of affiliated companies), somewhere in the world, and we first look at the domestic market. The number of patents filed is the largest in Germany. Many of them remain only in the domestic market. But a considerable share of all inventions [illegible] in the United Kingdom. So out of all countries in the world, the U.K. is the most preferred foreign market for Siemens in terms of protection of their inventions.

[3] OECD (ed.). *The Measurement of Scientific and Technological Activities: Using Patent Data as Science and Technology Indicators*. Patent Manual 1994, OECD/GD (94), 114, Paris 1994. A comprehensive bibliography on patent analysis is included in this source.

Table 1[4]
Analyzed Telecoms Manufacturers and Network Operators.

Company	No. of European patent applications in telecom technology invented 1987-89	Communications equipment (US $ m resp. international communications revenue 1993)
Alcatel NV	423	14,823
AT&T	378	11,801
Bosch	226	3,530
Ericsson	82	7,767
Fujitsu	288	4,774
GEC	181	1,948
Hitachi	83	1,555
IBM	342	5,299
Matshushita	100	2,227
Motorola	403	10,096
NEC	419	9,480
Nokia	78	2,355
Northern Telecom	110	7,860
Oki	27	1,590
Philips	378	1,868
Siemens	552	12,205
Sony	100	1,181
STET/Italtel	43	1,520
Thomson	132	n.a.
Toshiba	222	1,710
Bellcore	82	0 (domestic)
British Telecom (BT)	121	3,193
France Télécom (FT)	89	3,693
GTE-Sprint	39	1,188
NTT	86	0 (domestic)

[4] Data sources for patent statistics for (consolidated) company affiliations are Schmoch, U., and Th. Schnoring, Technological strategies of telecommunications equipment manufacturers, *Telecommunications Policy* 18 (5), pp. 397-414, 1994, and lengthier German data annexes cited therein (from 1992). Communications equipment revenues are from *Communications Week International*, pp. 16-17, Nov. 1995.

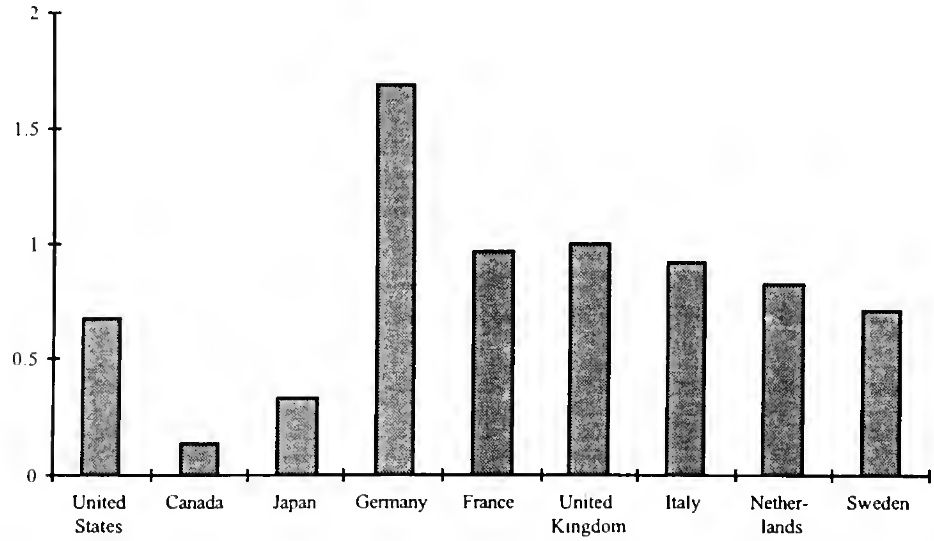

Figure 1.[5] Destination countries of telecommunication-related patent applications by Siemens (consolidated) 1987-1989.

This is explained by Siemens' serious effort to enter the British market, in part through patenting, in the late 1980's. Other large European countries are nearly equally covered with patents. For smaller countries, the patent applications declines. The number of intellectual property rights in the domestic market is less than double those abroad - so the company is quite international in its perspective. In the United States, though it is the single largest market in the world, the number of duplicated patents remains low despite the company Rolm which was acquired there producing some inventions. Siemens has neglected this country in comparison with Europe, and neglected Japan as well.

We can carry out a similar analysis for other companies as well. Table 2 provides similar information for the other companies. In this table, the number of patents filed in the foreign country with the most patents applied for is taken as the benchmark value of 1.0.

It is evident from Table 2 that GEC is the mirror image of Siemens - a British firm filing heavily in Germany; GEC and Siemens run a joint subsidiary, originating from the Plessey group. Note the behavior of Japanese companies. This is a statistical artifact. The patent law in Japan is such that they cannot easily accumulate and combine several claims to be protected in one document. In practise, each claim requires its own document. Experienced patent lawyers provide a rule of thumb - divide the number of Japanese domestic patent applications by six or so to arrive at roughly comparable numbers. So we cannot surmise that the patenting activity in Japan is as fast and furious as the numbers indicate.

[5] Source: Schmoch, U., International Patenting Strategies of Multinational Concerns: The Example of Telecommunications Manufacturers, in OECD (ed.), *Innovations, Patents and Technological Strategies*, pp. 223-237, Paris, 1996.

Table 2.
Destination countries for telecommunications-related patent applications for selected companies 1987-1989.[6]

	Destination country								
Corporation *(consolidated)*	**USA**	**CND**	**JPN**	**DEU**	**FRA**	**GBR**	**ITA**	**NLD**	**SWE**
Alcatel NV	0.71	0.71	0.49	1.28	1.09	1	0.97	0.92	0.89
Bosch	0.40	0.11	0.39	1.98	1	0.95	0.92	0.69	0.58
Ericsson	0.88	0.37	0.71	0.92	0.85	1	0.69	0.76	1.02
GEC	0.66	0.37	0.73	1	0.99	1.3	0.91	0.81	0.81
STET/Italtel	0.63	0.34	0.50	1	1	1	0.89	1	0.97
Nokia	0.28	0.06	0.32	0.95	0.94	1	0.81	0.71	0.82
Philips	0.92	0.19	0.85	1.10	0.98	1	0.69	0.44	0.59
Siemens	0.67	0.14	0.34	1.68	0.97	1	0.92	0.83	0.71
Thomson	0.97	0.13	0.48	0.99	1.23	1	0.76	0.52	0.43
AT&T	1.96	0.84	0.98	0.93	0.93	1	0.65	0.54	0.51
IBM	1.11	0.10	0.85	1	1	1	0.32	0.10	0.08
Motorola	1.51	0.44	0.94	0.95	0.95	1	0.90	0.92	0.90
NorTel	1	0.48	0.38	0.36	0.36	0.38	0.20	0.35	0.34
Fujitsu	0.9	0.69	31.46	1	0.93	0.99	0.25	0.11	0.23
Hitachi	1	0.11	12.19	0.54	0.33	0.39	0.07	0.06	0.05
Matsushita	1	0.12	3.2	0.66	0.53	0.70	0.13	0.27	0.26
NEC	1	0.50	3.81	0.58	0.43	0.69	0.11	0.29	0.26
NTT	1	0.50	44.8	0.87	0.51	0.79	0.14	0.27	0.52
OKI	1	0.19	20.95	0.53	0.47	0.57	0.15	0.04	0.19
Sony	1	0.27	5.25	0.85	0.78	0.89	0.11	0.34	0.04
Toshiba	1	0.32	13.34	0.54	0.33	0.47	0.05	0.08	0.13

[6] Source as in footnote to Figure 1. The European coverage is most frequently achieved via European patent application. Patenting in one European Union country does not automatically confer a patent in all other countries of the European Union, as is sometimes mistakenly believed, since the European Patent Office (EPO) has come into being in 1978. But it works as follows: you send in your invention to the EPO. You specify for which member countries you seek patent protection. They make a joint examination, which is costly (compared to a single national examination - say 5 times as much), but once done and when successful, it is handed over to the national patent offices, and without further investigation, it is accepted. If you choose this route, then count this document in a multiple way, for all designated countries. What you save, as a company or patent applicant, is simply the examination procedure, time and translators and attorneys' fees. But ultimately the *national countries* grant or decline the patent protection in their own country. This is a clear distinction to the so-called International Patent which has to be transferred from the international to the national stage whereby costs accrue in each transferred system. Note that the EPO member states are not synonymous with the European Union. They include Switzerland, Liechtenstein and Norway - some 18 member states are involved presently, in contrast with 15 for the EU members.

To this point, the strategic marketing aspect of innovation, as revealed in patent applications by protected national markets, has been analyzed. It was seen that potential strategic initiatives of companies in foreign markets can be tracked. In analyzing these data, one arrives at the conclusion, that in the telecom industry there are several, very different strategic positionings of companies at the end of the 1980's (see Table 3). There is a group of companies from various countries, which have an average share of broad patents. We have another group of companies, selective in patenting their inventions abroad among them some Japanese manufacturers. Then we may discern a group of companies with a special focus on the American market. Finally, there are companies with special focus on the Japanese market. And, another group of companies - among them newcomers in that market - that do little on the Japanese market. What do we know about how these companies position themselves in the overall information technology arena, with their telecom activities? Are they broad, or narrow, in technological terms? This is a typical multidimensional problem. Here we offer a brief introduction to a statistical technique known as multidimensional scaling. Suppose you were given a typical triangle of road distances between pairs of major European cities. For, say, 8 cities, there are 8 x 7 / 2 = 28 such distances. Now, suppose you were asked to place these cities on a two dimensional map, such that the distance between each pair of cities precisely matches the distance noted in the table. The task: Write a computer algorithm that will do so. There are such algorithms, and they position each "city" (which in some cases is a variable, technology, or a company), state whether the "map" is accurate or not (in terms of a coefficient of goodness of fit), and provide other types of useful information. This is multidimensional scaling (MDS), a version of which is also known as smallest space analysis (SSA). Note that there is an exact solution only in the (28-1) dimensional space, as our starting point is road distances not air distances taken from the two-dimensional surface of our globe as usual. Let us conduct an MDS analysis of IT. We take the telecom manufacturers (including for comparison the network operator in Japan, NTT),[7] 10 use their patent profiles over technological entities (a fine classification exists, including more than 70,000 individual items, the International Patent Classification), and define six major fields in information technology, telecom (TELCOM), electronic elements (ELTRN), multimedia technology (or audio-visual or consumer electronics, (AVEL), optical technology (OPTICS), storage (STOR) and data processing (DAT). We then compare the profiles of any two companies to see whether they are similar or not.

Table 3
Typical patent strategies of selected companies on foreign markets.[8]

Feature	Examples
Average share of foreign patents, broad coverage	Alcatel, AT&T, Philips, Siemens
Generally, little foreign patenting, but broad coverage	Ericsson, GEC, Motorola, many network operators
Selective strategy	Hitachi, Oki, Matsushita, NorTel
Special focus on the American market	Matsushita, Hitachi, NEC, Thomson, Philips
Special focus on the Japanese market	AT&T, IBM, Motorola, NorTel, Philips
Low presence on the Japanese market	Bosch, Nokia, Siemens, STET, Thomson

[7] This is justified, as the NTT labs develop IT technology in collaboration with Japanese manufacturers which is patent-protected by NTT; see Grupp, H., Efficiency of government intervention in technical change in telecommunications: Ten national economies compared. *Technovation* 13, (4), pp. 187-220, 1993.

[8] Source: Schmoch, U. and Th. Schnoring, Technological strategies of telecommunications equipment manufacturers, *Telecommunications Policy* 18(5), pp. 397-413, 1994.

(We calculate the correlation coefficient of each pair of company technology profiles). Two companies which each put 16.6 % of patenting activity in each of six fields will have a correlation of one. Two companies each of which puts 100 % of its patenting activity into a different field, will have a low correlation ($R^2 = 0.2$ in the example). They are thus considered dissimilar.

Figure 2 shows a multidimensional scaling map of companies, where distances in the diagram represent similarity - Euclidean proximity. To understand the MDS map fully, as with any map we need a convention or wind rose, a "north" and "south" in IT. An artificial "North" and "South" is created as follows. We invent an artificial company, one that doesn't exist and that is active in one subfield - say, multimedia or consumer electronics. For this field, we assign all this imaginary company's patenting activity, 100 %. Then this company becomes a "pole" - one can compare all other companies to this virtual company that is the strongest possible in this field. We thus create fictitious companies to represent the "pole" in optics, in electronics components, and so on. This map of technological profiles, in terms of several poles, represents real findings and not artificial ones. Looking at single companies validates this method - and we have. This is the simplest way to benchmark individual companies relative to other firms - each company can recognize their closest competitors as those that have the most similar profiles.

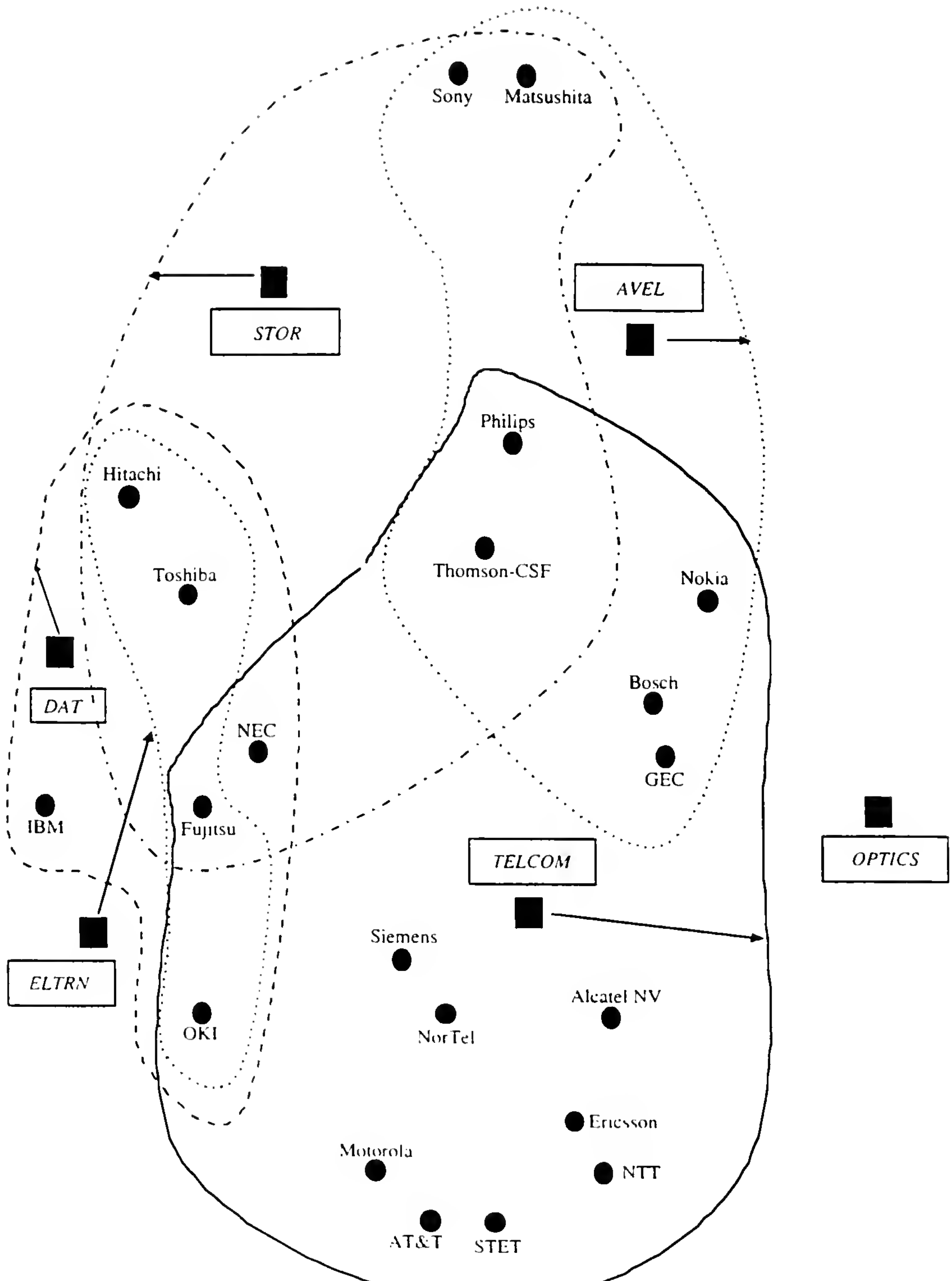

Figure 2. MDS map of information technology for selected companies in the period 1987 to 1989.[9]

[9] Source: Schmoch, U., Evaluation of technological strategies of companies by means of MDS maps. *International Journal of Technology Management* 10(4-6), pp. 426-440, 1995.

Now, let us zoom down to a more limited market - only telecoms. We introduce an MDS map based on a breakdown of patenting in subfields (Figure 3). We get in principal the same thing, but just a window of the larger map. We see groupings of companies who are strong in optical telecommunications (OPT T), switching (SWIT), mobile radio telecoms (RATIO T) and electrical transmission (ELKT T - remote measuring and sensing), and terminals technology (TRML). The map provides us with an interesting picture: we now know who are the strong innovators in optics, in transmission - Toshiba is a newcomer, so we get new information on new entrants in this field where we may not have subject information before. The network operating companies - with the exception of NTT - support the national innovation systems mainly with optical technology, an important ingredient to modern telecoms networks. Whereas at the end of the 1980's, everyone was competing with everyone, at the beginning of the decade, there were islands of specialization, a nice partitioning of the markets. After the opening of the telecom markets through deregulation, there was fierce competition in nearly all markets. This is what a similar MDS map would show, for the beginning of the 1980's. From several snapshots of the MDS strategic positions, you can make a movie, combining them, to get a dynamic picture.

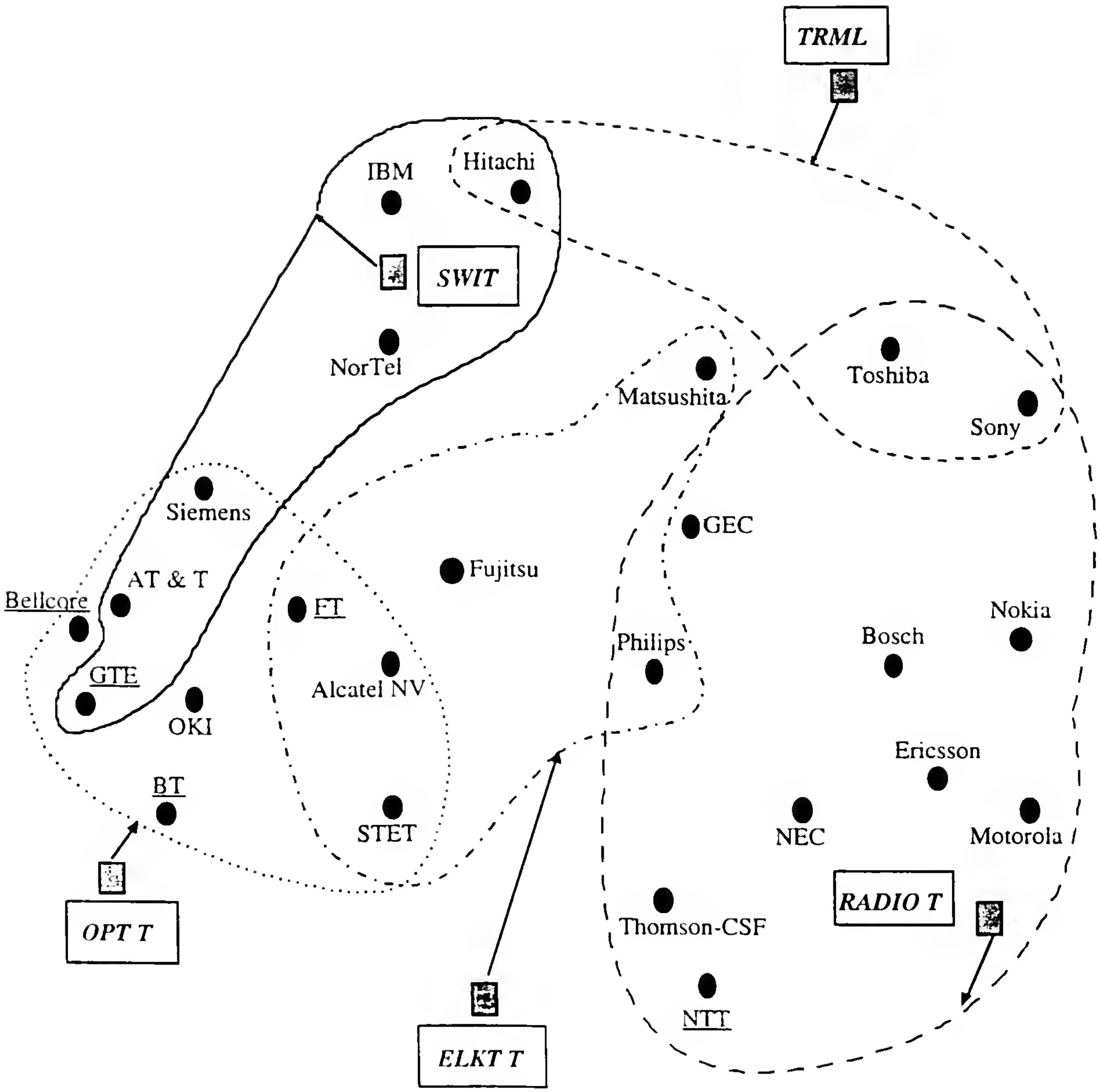

Figure 3. MDS map of communications technology for selected companies in the period 1987-1989.[10]

[10] Source as in footnote of Figure 2. Network operators underlined.

3. Knowledge production and growth - the innovation module

Timelines of technical results and newness of the company's technology portfolio strongly affects its innovation performance and - more specifically - new product revenues.[11] The lessons for clarifying the role global technology knowledge plays for the technology levels to be achieved are two-fold. First of all, in general terms, the more patents with international significance a company takes out the more sophisticated its product innovations seem to be. On the other hand, some companies offer very sophisticated products on world markets with no comparable patent production.[12]

There are three possible explanations for the latter observation. First, companies may have a very good tacit in-house knowledge base in the relevant technology, or rely on secrecy or very short market introduction times and do not care for comprehensive, international protection. Another possibility would be that companies have a strong domestic patent base but do not take out foreign duplications of their inventions, accepting all the associated international market risks. This case can be checked by an analysis of patent flows (Table 2) and can be ruled out. The third possibility is that the companies produce excellent products from global knowledge external to the company. By acquiring leading- edge companies, licensing, networking and other forms of technology cooperation they may produce innovative products from creative technologies of other firms (including public laboratories). This is an important element in telecommunications.[13] From this analysis it is concluded that there are various ways to innovation. Some companies acquire technological knowledge from other, e. g. global sources instead of using intramural technology generation and patent protection. But not all companies can do so in telecoms, so that for a number of companies a knowledge production relationship between in-house technology generation and innovations achieved should appear to be established. Furthermore, technology generation anticipates innovation performance levels for some years. Patent stock data for previous years should fit better to the technology levels than the most recent activities as cumulative technology acquisition by firms is so important. The "knowledge production function" for innovation as measured by the growth levels of innovative products can be modeled as follows (this is a further development of the knowledge production function model of Griliches):[14]

It is a one dimensional approach taking some scalar output measures as is shown below. If we, however, want to use qualitative, non-pecuniary proxy measures, i. e. for product quality, we cannot use the conventional production models. A version of linear programming exists, however, that was explicitly built to measure the efficiency of decision-making units (which can be individual firms) and that does allow qualitative inputs. This approach is known as Data Envelopment Analysis (DEA). Essentially, it examines which decision- making units (DMUs) are on their production possibilities frontier, or isoquant in the knowledge economy and which are not. [15] Here we try out how far the scalar approach holds.

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[11] Roberts, E.B. Benchmarking the Strategic Management of Technology: II - R&D Performance. MIT Sloan School of Management, International Center for Research on Management of Technology, WP #119-95, 1995.

[12] See H. Grupp. Technical change in a global market: competition in solar cell development. 23rd annual E.A.R.I.E. Conference, Vienna, September 1996.

[13] Compare the national R&D infrastructures in Grupp (1993, loc. cit).

[14] Summarized in Griliches, Z., R&D and Productivity: Econometric results and measurement issues, in Stoneman, P., ed., Handbook of the economics of innovation and technological change, Basil Blackwell, Oxford, pp. 52-89, 1995.

[15] See, e.g., H. Grupp (1996, loc. cit.), or Grupp., H., S. Maital, A. Frenkel and K. Koschatzky. The relation

The knowledge production function approach can be represented in the following way:

$$Y = a(t)\, K^{\beta} + u$$

where Y is some measure of output of the firm, K is a measure of cumulated knowledge or research "capital", a(t) represents other determinants which affect output and vary over time including standard economic inputs such as capital investment, labor and so forth while u reflects all other random fluctuations in output.

Certainly, this is just a first approximation to a considerably more complex relationship.[16]

From the logarithmic form we arrive at the growth equation

$$d \log Y / dt = (1/Y)\, dy / dt = a + \rho\, (R/Y) + du/dt$$

where the term (d log K)/dt is replaced by using the definitions $\rho = dY/dK = \beta\ (Y/K)$ and R=dK/dt for the net investment in knowledge capital. We now calculate the deflated growth in communications equipment revenues 1993 in comparison to 1986 [17] and approximate R by the number of patent applications following the base year 1986, i.e. inventions in the priority years 1987-89. This is a, "skeletal" model of depreciation and obsolescence of (patented) knowledge, but more realistic data are difficult to obtain. It means, that inventions from 1986 or earlier years do no more matter for the revenues in 1993, and inventions from 1990 and later do not yet. Patent application number always measure the increase (dK/dt) in knowledge as they add up to the already existing (and eventually patented) knowledge. The assumed lag of about four years until novel knowledge affects markets is taken from earlier empirical investigations. [18] Cross-section linear regression analysis of the 19 manufacturing companies in Table 1 gives the results as displayed in Table 4.

Knowledge production explains parts of the variance significantly although all the other potential inputs (labor, physical capital, tacit knowledge) are included in the residuals only. A visual impression of the relation is provided in Figure 4.

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between technological excellence and export sales: A data envelopment model and comparison of Israel to EC countries, Research Evaluation 2 (2), pp. 87-101, 1992.

[16] Griliches, loc. cit., p. 55.

[17] Using OECD's implicit GDP price indexes.

[18] Grupp, H., Innovation Dynamics in OECD Countries: Towards a Correlated Network of R&D Intensity, Trade, Patent and Technometric Indicators, in OECD (ed.), Technology and Productivity - the Challenge for Economic Policy. Paris, pp. 275-295, 1991.

Table 4
Regression results for the knowledge production function of telecom manufacturers (revenue growth 1993 compared to 1986).

Measure / Variable	Value
ρ	0.0053 ± 0.0018
Constant	0.6312 ± 0.3700
R^2 adjusted	0.298
F	8.652
t	2.941
Significance	0.91 %
DW	2.296

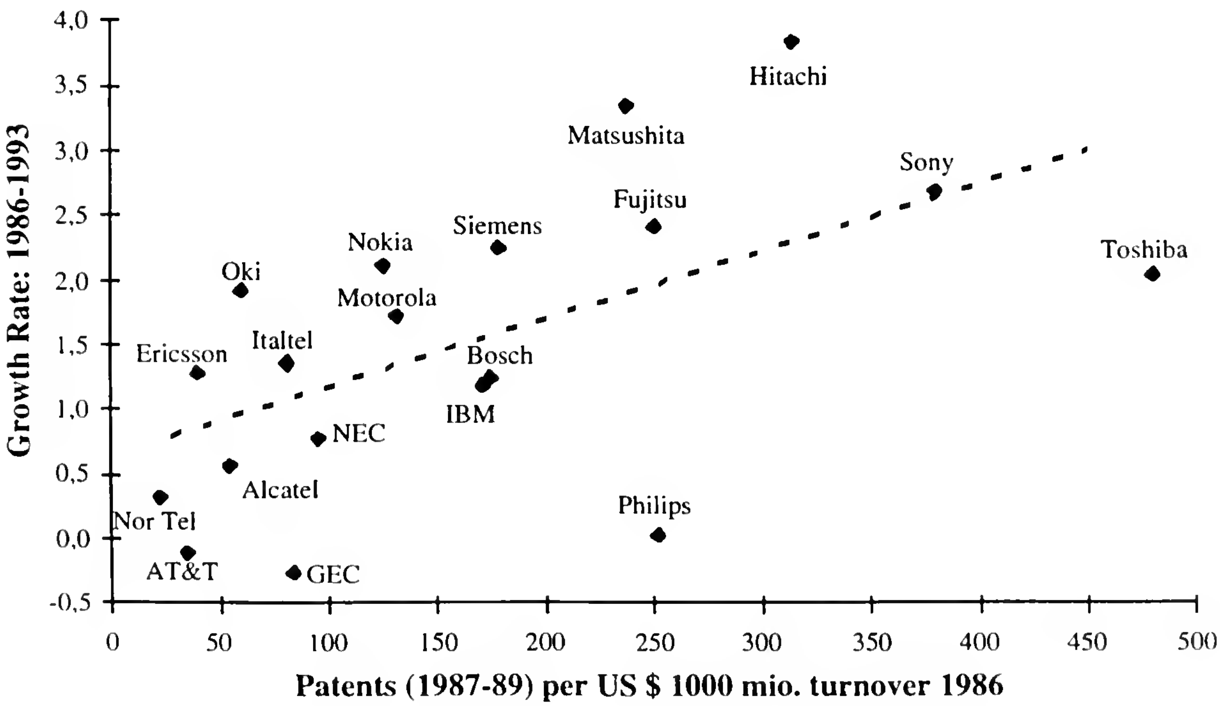

Figure 4. Deflated growth of corporate revenues and knowledge production of telecom manufacturers.

strong R&D performers. They failed to convert this into innovations that led to average growth of revenues in this particular market for telecoms goods. This is not to talk managers into a reduction in R&D activities, rather, to adjust the innovation "module" in a more effective way to reach better yields of knowledge investments. Newcomers in the telecoms market such as Matsushita or Nokia grew so quickly with modest own knowledge sources[19] that one is tempted to express a word of warning: Long-term sustainable growth may be vulnerable if you depend too much on external or tacit knowledge sources.

4. Technometric Benchmarking for Individual Products: The Case of Optical Communications Lasers

After examining broader industry trends, it is possible to "zoom down" to the product level, using a different approach. Here, patent statistics cannot help. In an invention, it is not specified what the product characteristics will be like. We need another instrument of analysis of product innovation quality - one known as technometrics. We have the following starting point. A product is described by its characteristics. Consumers do not buy "products", rather they purchase a combination of characteristics or attributes, that satisfy their wants and needs. For example, a laser is described by wave length, power, stability, and so on. In general, experts know which are the important characteristics. But the problem is, each characteristic has a different unit of measurement. So it is not a vector - you cannot derive a comparable measure.

The technometric concept converts it into a metric scale, a dimensionless one, all features between zero and one - which enables us to build a profile that can be compared one to another, one attribute to another, one product to another.[20]

Figure 5 provides a graphical illustration of technometric profiles for seven different products, and three different possible patterns. Technometric benchmarking makes it possible to construct a detailed profile of the product, comparing one characteristic only across products. One can also look at the entire profile of a single product, across all characteristics, without weights - simply draw all the 0,1 values. Only if you want a one-dimensional scalar number, to aggregate the technometric scores, does one need weights for each prodattribute. The weights are, of course, representative of the preferences of customers. They can be determined by market surveys, focus groups, or, at times, by eliciting the opinions of those engaged in direct marketing of the product.

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[19] The growing importance of acquiring technology from outside sources is undeniable; see, e.g., the benchmarking study by Roberts, E.B., Benchmarking the Strategic Management of Technology - I. MIT Sloan School of Management, ICRMOT, Working Paper # 115-94, Cambridge, MA., 1994.

[20] Earlier concepts of technometrics, such as H. Grupp., The measurement of technical performance of innovations by technometrics and its impact on established technology indicators, *Research Policy* 23, pp. 175-193, 1994, or Frenkel, A., Th. Reiss., S. Maital, K. Koschatzky, and H. Grupp, Technometric Evaluation and Technology Policy: The case of Biodiagnostic Kits in Israel. *Research Policy*, 23, pp. 281-292, 1994, were not focused on benchmarking. The technometric procedure applied to benchmarking is best described in Shoham, A., H. Grupp, S. Lifshitz, and S. Maital, "Technometric benchmarking: Identifying sources of superior customer value," forthcoming, 1996. We omit the mathematical expressions here; see the above sources for these.

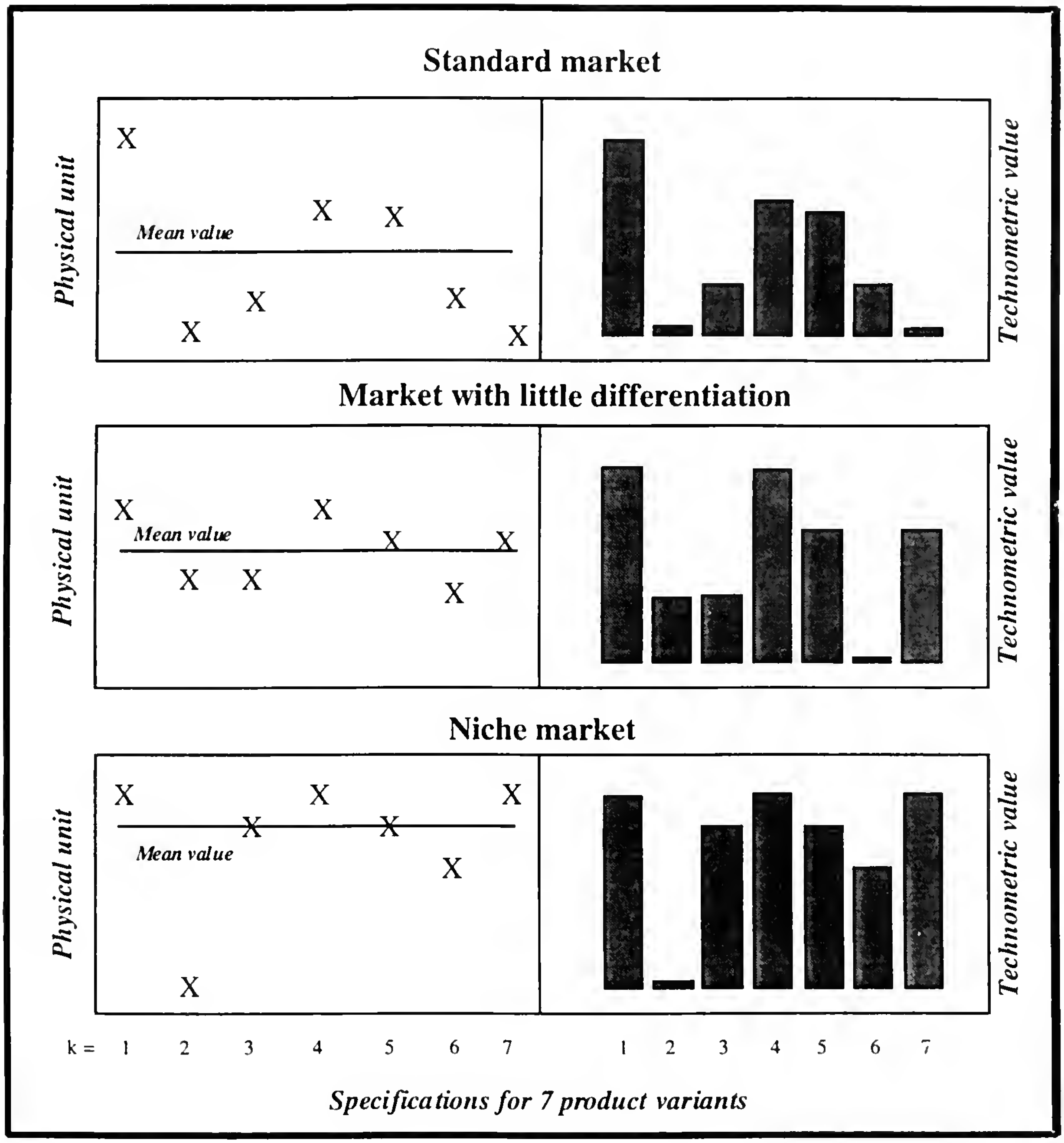

Figure 5. Sketch of technometric benchmarking concept.

Figure 6 provides a profile of product quality for laser diodes, of mm range, for telecom applications in optical fibres, presented in the following way: The world state- of-the-art level is set to one. This changes over the course of time, but is equal to one at a given point in time. For Japan, all Japanese manufacturers are aggregated, as if they were a single firm ("Japan Incorporated"). In some attributes, they are world- class, in others, well below it. In laser power, at least one Japanese manufacturer offers world-class quality. In others, no Japanese manufacturer attains world-class sophistication. This holds for all Japanese companies taken together.

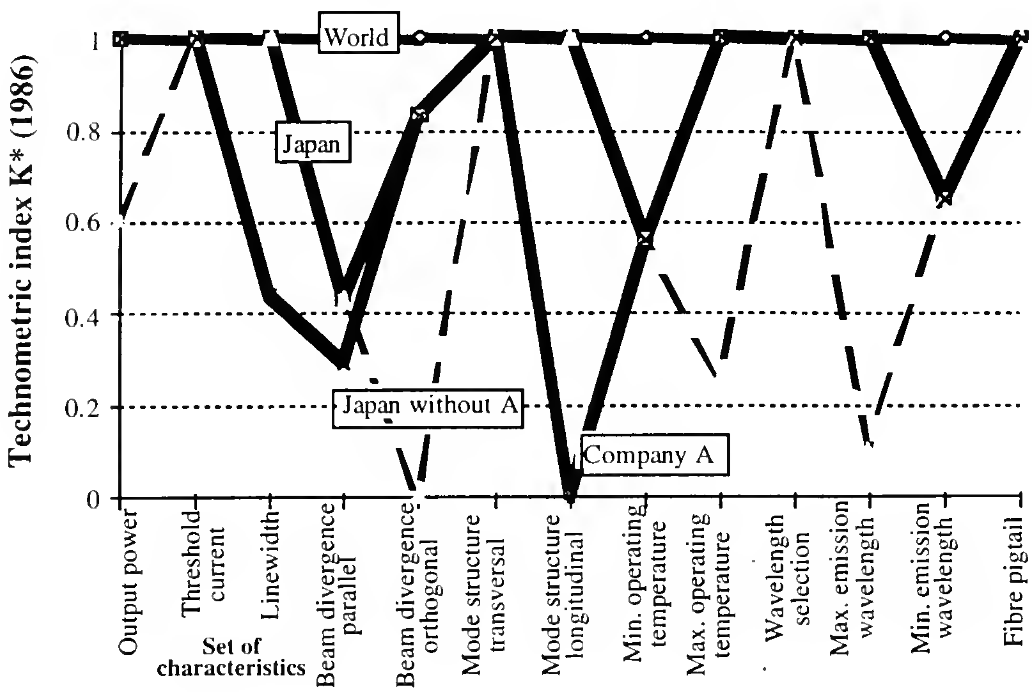

Figure 6. Example for product quality measurement for single products and domestic market aggregation: Laser diode in the μm range for optical communications.

The broken line portrays a specific company, Company A. It has products, laser diodes, on a world level, in part, and below world level, in part. One can see precisely strengths and weaknesses at one glance. So this, of course, is the adequate "zoom" for benchmarking Company A against Japanese competitors. This is a typical application of technometrics for benchmarking the products of company A for the domestic Japanese competition. Of course, in such a case, Company A can search for a remedy for this situation, if it indicates weaknesses - by looking abroad, for those who have a technological solution. In other cases, one can search for a strategic partner in Japan.

Figure 7 shows a technometric comparison of laser diodes in the micrometer range, not suitable for optical communication. There is Company A, German, and a line for Germany without Company A, and the world class - the present profile of all Japanese and all US companies. Company A will learn from this, whether there are German competitors better than itself, and whether there is expectation that one can find a partner for a strategic alliance in Germany - and if not, to which other country might one look. This is exceedingly useful for strategic innovation. For an overall measure of product quality index, one dimensional, we can do this only if we have preferences of customers, showing what weights they give each single characteristics. There are several methods. You can ask people, a sample of them, how they would value single characteristics. You can devise this from prices - the method of hedonic price indexes - by seeing the statistical link between product prices and their attributes, with coefficients of attributes indicating the importance of those attributes. Such information is presently not available for laser diodes in optical communications.

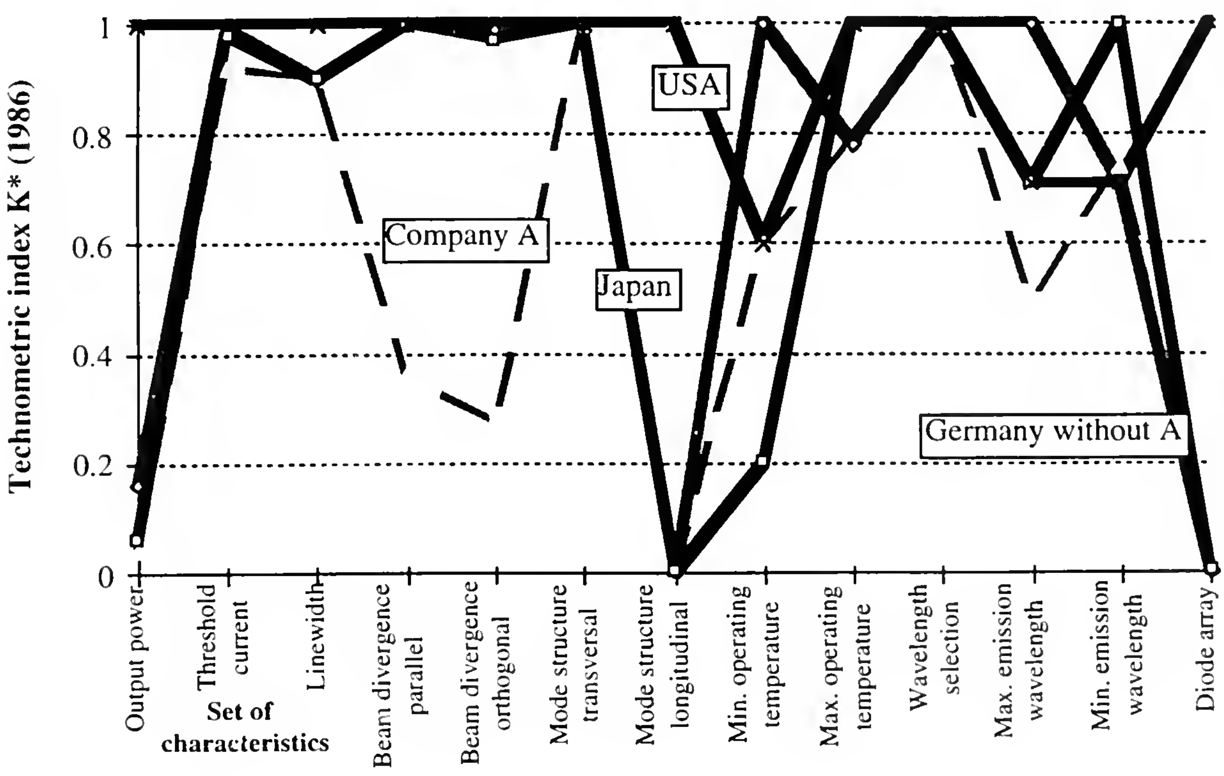

Figure 7. Example of product quality measurement for single company products and international comparison: Laser diodes in the μm range.

5. A Typology of Strategic Focus

One can construct a kind of typology of companies and their technological strengths or weaknesses, building on the technometric profiles. There are four basic types of firms (see Figure 8):

* uncompetitive,
* unfocused,
* focused, and
* dominant.

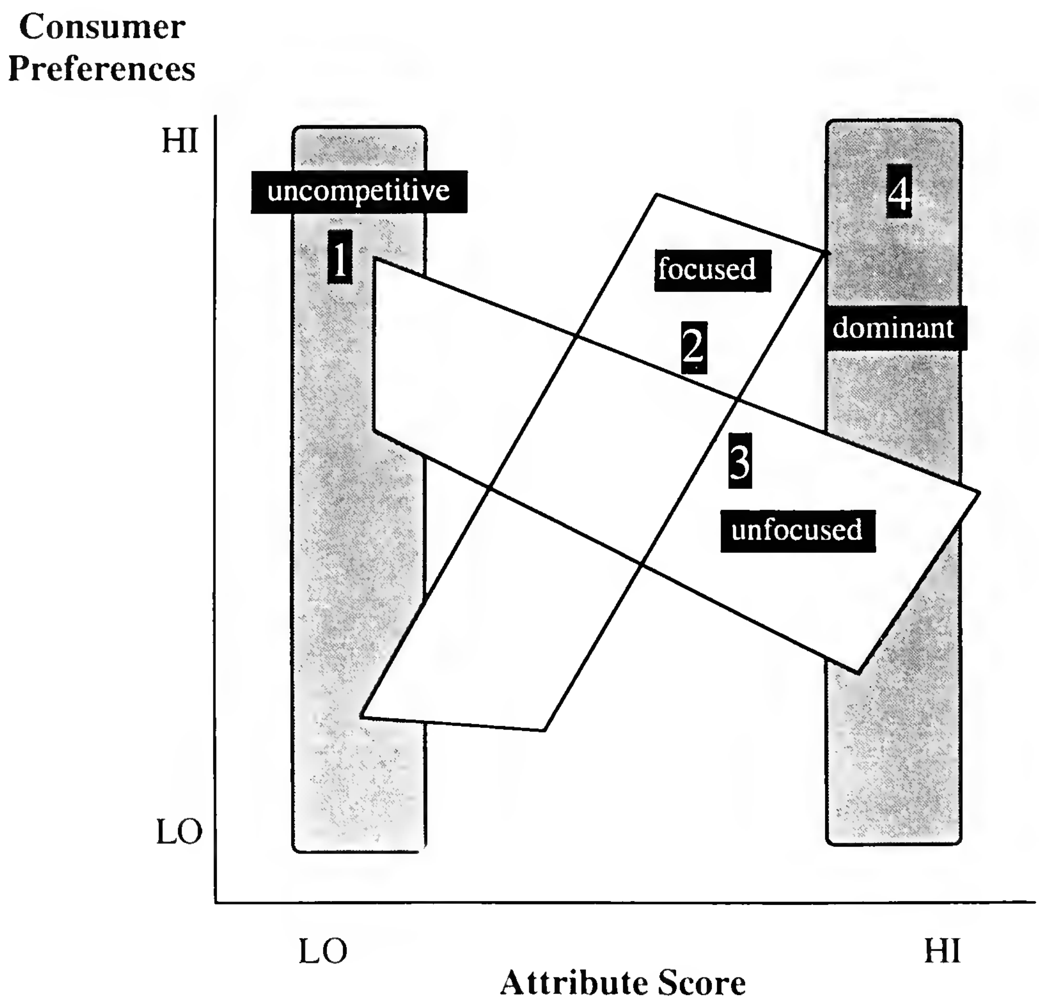

Figure 8. Typology of Firms. Focused firms have product strength for attributes consumers regard as important.

One sees this by mapping firms' products in two- dimensional space, with the X axis indicating, for each attribute of a product, its technometric score (from zero to one), and the Y axis indicating, for each attribute, the weight or importance of that product in the eyes of its consumers. In other words, a product with 10 key attributes will be characterized by 10 pairs of numbers. The first

number in each pair, the X value, represents the attribute's objective, technometric score, and the second number, the Y value, indicates the subjective consumer preference weight.

The way those 10 points cluster establishes a firm's competitive position. If the firm's product is consistently weak relative to its competitors, it is "uncompetitive". This is shown by an essentially vertical line rising from "LO" product quality. Its market success is highly dubious. If the firm's products are technometrically strong for attributes consumers rate as unimportant, and vice-versa - technometrically weak for attributes consumers rate as important, then the firm's product is unfocused, or rather misfocused. Its market share is unlikely to be high or growing. If the firm's products are strong for attributes consumers rate highly, but weak for attributes consumers think unimportant - the product is focused, and market share will be strong.

Finally, if the product is technometrically superior for all its attributes - then the product is defined as dominant". The first type of firm, "uncompetitive", has uniformly low product quality, for attributes consumer value highly as well as for those they value less highly. These firms are uncompetitive, unless their products compete on the basis of very low price (and hence, are produced at low cost). The second type of firm is "focused". These firms are strong precisely in attributes that the market values highly. Their R&D tends to be well directed and strategically planned in line with market preferences. The third type of firm is "unfocused" - their product quality is strong precisely for attributes the market as relatively unimportant, perhaps as a result of poor R&D investment.

Finally, there are dominant firms. These firms have consistently high product quality across all attributes, both relatively important and relatively unimportant ones. They tend to dominate their markets. We anticipate a positive link between the performance of companies and their products, and their placement in the above typology. Uncompetitive or unfocused products should fare more poorly than those that are focused and dominant. As more elaborate data are missing for telecommunications, we presently cannot provide examples. Such analysis remains on the research agenda; the feasibility of this strategic analysis has already been shown for sensor technology. [21]

Conclusion

This is only a preliminary study of a new approach to innovation benchmarking, as applied to telecom and information technology. Management always should begin with measurement. This is especially true of the difficult and risky task of managing innovation. By quantifying aspects of the innovation process, hopefully management decisions can become fact-based and hence lead to superior performance.

[21] Grupp, H. and S. Maital. Interpreting the sources of market value in a capital goods market - The case of industrial sensors. *R&D Management*, forthcoming 1996.

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